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DETAILED REPORT

(Name of the invention)

Plasma display and manufacturing method for the same

Outline

(Object)

This invention offers a plasma display which has cell walls that do not have delamination or swelling at ends..

(Solution)

The object of this invention can be attained by a plasma display which forms the cell walls 2 using a mother mold for the cell walls, glass paste which consists mainly of glass powder and an organic component, and a glass substrate 1. The ends of the cell walls are tapered. The height (X) of the cell walls and length (X) of the taper satisfy the following formula:

$1 \leq X / Y \leq 100$

Sphere of patent request

(claim 1)

Claim 1 is regarding a plasma display which has the following characteristics: This plasma display forms cell walls 2 using a mother mold, glass paste which consists mainly of glass powder and an organic component, and a glass substrate 1. This mold has tapered ends of the cell walls. The height (X) of the cell walls and length (X) of the tapered part of the cell walls satisfy the following formula:

$1 \leq X / Y \leq 100$

(claim 2)

Claim 2 is regarding the plasma display in claims 1 where the angle of the taper is 5 to 60 degrees.

(claim 3)

Claim 3 is regarding the plasma display in claim 1 or 2 where the length of the taper is 0.5 to 5 mm.

(claim 4)

Claim 4 is regarding a manufacturing method for a plasma display which has the following characteristics: A mother mold with stripe shaped grooves is filled with glass paste which consists mainly of glass powder and an organic component. The open side of the mother mold is pressed onto a glass substrate; the glass paste in the grooves of the mother mold is transferred to the glass substrate; and the molded glass paste is sintered on the glass substrate at

400 to 600°C. The process follows these steps in this order. In this manufacturing method, the ends of the grooves formed in the mother mold are tapered in the direction of depth.

(claim 5)

Claim 5 is regarding a manufacturing method for a plasma display which has the following characteristics: The glass paste which consists mainly of glass powder and an organic component is spread on part or all of the surface of the glass substrate at a uniform thickness. The cell walls are formed in this layer of paste by pressing the mother mold with stripe shaped grooves on the layer of paste; and the glass paste on the glass substrate is sintered at 400 to 600°C, in this order. In this manufacturing method, the ends of the grooves in the mother mold are tapered in the direction of depth.

(claim 6)

Claim 6 is regarding a manufacturing method for the plasma display in claim 4 or 5 where the mother mold is made of polymer resin or metal.

Detailed explanation of invention

[0001]

(Technical field of this invention)

This invention is concerning a plasma display and its manufacturing method.

[0002]

(Prior art)

A plasma display (PDP) has high speed compared to a liquid crystal panel, and it is also easy to make in a large size. Therefore, it is used in the field of OA equipment, information display devices, etc. In addition, development into the field of high definition TV is very much expected.

[0003] With the growing demand for larger devices such as the above, a color plasma display which has fine resolution and many display cells has been gaining attention. To explain the AC plasma display, for example, a plasma electric discharge is produced between opposing anodes and cathodes inside the electric discharge space between the front glass substrate and back glass substrate. UV rays produced by the gas sealed inside the electric discharge space irradiate a layer of luminous material inside the electric discharge space. This processes makes a display. Figure 1 is a simple figure which shows the construction of an AC plasma display. The electric discharge is contained in a fixed area and the display is illuminated inside the regulated cell. At the same time, in order to form a uniform electric discharge space, cell walls (blocking walls, also called ribs) are set up. In the case of an AC plasma display, these cell walls are formed into stripes.

[0004] The cell walls above are approximately 30 to 80 μm wide and 70 to 200 μm high. Normally, an insulating paste which includes glass powder is screed printed and dried on the front glass substrate or back glass substrate. This process is repeated more than 10 times in order to form cell walls with the desired height.

[0005] Japan patents No. H 1-296534, No. H 2-165538, No. H 5-342992, NO. H 6-295676, No. H 8-50811 suggest a method of forming cell walls using a photo-sensitive paste by photo lithography techniques.
[0006] Japan patent No. H 9-134676 suggests a substrate for a plasma display which consists of a molded body acquired by filling a mold with grooves for cell walls with a mixture of binder and glass powder and pressing it on a glass substrate.
[0007] In any of the above methods, cell walls are made by forming an insulating paste which includes glass powder into a cell wall pattern and sintering it. However, according to these methods, as shown in figure 3, the lower part of the ends of the cell walls 2' rises up from the glass substrate 1' because of the difference in shrinkage due to sintering between the upper part and lower part of the cell walls. Also, as shown in figure 4, even when it is bonded to glass substrate 1'', the upper part of the cell walls 2'' swells up.
[0008] When this delamination at the ends of the cell walls occurs, gaps are formed between the tops of the cell walls and the back and front plates when the panel is assembled by pasting the front and back panels together. Because of these gaps, cross talk is produced during electric discharge, which causes disturbances in the screen image.
[0009] A method of solving this problem is suggested in Japan patent No. H 6-150828. In this method, the composition of the upper and lower layers is changed by making the cell walls a multi-layer structure. Glass with a lower melting point is used in the lower layer. In addition, Japan patent No. H 6-150831 suggests a method which sets up a glass foundation layer under the ends. However, none of these methods is sufficient to eliminate the difference in shrinking stress even if they do improve bonding between the cell walls and foundation. These methods are not sufficient to prevent swelling.
[0010] Also, Japan patent No. H 6-150832 discusses a method which makes the ends of the cell walls stepped. However, this is also insufficient to prevent delamination of the cell walls at the ends since the ends have a right angle shape and cannot compensate for the difference in shrinkage stress. This method is not sufficient to prevent swelling.

[0011]
(Problems that this invention tries to solve)

The object of this invention is to offer a highly precise plasma display which eliminates delamination of the cell walls at the ends and also has much less cross talk.

[0012]
(Steps for solving the above problems)

The object of this invention can be attained by a plasma display which forms the cell walls 2 using a mother mold for the cell walls, glass paste which consists mainly of glass powder and an organic component, and a glass substrate 1. The ends of the cell walls are tapered. The height (X) of the cell walls and length (X) of the taper satisfy the following formula:

[0013] $1 \leq X / Y \leq 100$

The plasma display in this invention works by electric discharge inside the electric discharge space which is separated by the cell walls. In addition to the above AC plasma display, this invention includes various kinds of electric discharge displays starting with plasma address liquid crystal displays.

[0014]

(State of practice of this invention)

Figure 1 is a cross section of one example of the cell wall ends in the plasma display in this invention. Cell walls 2 are formed on a glass substrate 1. In this invention, making the ends of the cell walls tapered prevents delamination and swelling of cell walls due to difference in shrinking of the upper and lower parts of the cell walls during sintering.

[0015] In addition, a tapered part should be formed on both ends of the cell walls to prevent an uneven gap between the front and back panels during assembly.

[0016] Any shape can be used for the taper such as (1) straight (2) convex curved line, (3) concave curved line, (4) multiple straight line segments can be used as long as height is reduced toward the very end of the cell walls.

[0017] The height of the cell walls excluding the tapered part at the ends should be less than 50 μm. If it is less than 50 μm, swelling is minimized. When a panel with 20 inches wide or more is formed, the panel is affected atmospheric pressure, and the front panel and cell walls are tightly bonded, and cross talk becomes even less likely to occur.

[0018] In this invention, the height of the cell walls (Y) and length (X) of the taper must satisfy the following relation: $1 \leq X / Y \leq 100$. That is, the taper should be longer than the height of the cell walls to prevent delamination or swelling. Figure 2 shows the length (X) of the tapered part of the cell walls and the height of the cell walls (Y). As shown in figure 2, the height (Y) is the average height of the cell walls 2 excluding the tapered part. The length (X) of the tapered part of the cell walls is the distance from the point where the height starts to decrease to the very end of the cell walls in section.

[0019] If X/Y is less than 1, this will not relieve stress due to shrinkage during sintering. On the other hand, if it exceeds 100, the tapered part becomes too big, and the electric discharge space is reduced. As a result, the functional area of the display will be small, which is not desired.

[0020] The tapered part cannot be used in the electric discharge area since it is naturally lower than the desired height of cell walls and it produces distortion in the screen image. Therefore, the upper limit of X is determined naturally, and 10 mm or less is good, preferably 5 mm or less. However, in the case when it is less than 0.5 mm, it is less effective in controlling delamination or swelling due to forming the taper. Therefore, X should be in the range of 0.5 to 10 mm, preferably 0.5 to 5 mm.

[0021] In addition, the angle of the taper should be 5 to 60 degrees. If it is less than 5 degrees, the taper will be too long, causing design problems. On the other hand, if it exceeds 60 degrees, it cannot control delamination during sintering. A more desirable range is 20 to 50 degrees.

[0022] This range is concerning the shape of the cell walls. However, the range of allowable cell wall shapes before sintering will be naturally determined also. For example, when the height of the cell walls is y, the length of the bottom which forms the taper is x, and the shrinkage ratio is r, $X = x$, $Y = y \times r$. When this is applied to the above formula $1.0 \leq X / Y$, $x/y \geq 1.0$ r.

[0023] In this invention, the taper can be measured using an optical microscope, scanning electron microscope, or laser microscope.

[0024] For example, when a scanning electron microscope (HITACHI S-2400) is used, the following method is preferred. First, the sample is sectioned so that the ends of the cell walls will show up accurately, and it sized to fit the instrument. The area where the taper shape comes into view is selected for magnification. After the scale is edited to show a standard sample the same size as the taper shape, a photo is taken. The length of X and Y which are shown in figure 2 is measured, and the shape is calculated from the scale.

[0025] When a non-destructive measurement is desired, it is possible to use a laser focus displacement measurer (for example, LT-8010 manufactured by Keyence). In this case also, the measurement should be done after editing with a standard sample. The measurement surface of the laser must be parallel to the stripe direction of the cell walls in order to perform an accurate measurement.

[0026] In addition, it is desired that specific weight of the cell walls that are formed in plasma display of this invention is 2 to 3.3. In order to make it under 2, the glass materials must contain a large amount of oxide of alkali metal such as sodium oxide or potassium oxide. Since this will lower electric discharge properties by evaporating during electric discharge, it is not desired. On the other hand, if it exceeds 3.3, the display is heavy when it is used for a large screen, and the substrate warps under its own weight, which is not desired.

[0027] Next, a manufacturing method for the plasma display of this invention is going to be explained.

[0028] The following is a manufacturing method for the plasma display in this invention, for example: A mother mold is filled with glass paste mainly consisting of glass powder and an organic component. The mother mold has stripe shaped grooves. The open side of the mother mold is pressed onto a glass substrate. The glass paste is transferred from the grooves in the mother mold to the glass substrate. The glass paste is sintered on the glass substrate at 400 to 600°C. The process takes place in this order. In this manufacturing method, the ends of the grooves formed on the mother mold are tapered in the direction of depth.

[0029] In this method, grooves in the mother mold corresponding to the cell wall pattern are formed beforehand. Glass paste is used to fill the grooves and then this paste is transferred to the glass substrate from the mother mold to form a cell wall pattern. In this method, after the mother mold is filled with glass paste, it is transferred to a glass substrate to form a cell wall pattern. By applying pressure during this transfer, defects can be minimized. In addition, if heat is applied during the transfer process, removal of the paste from the mother mold becomes easy. Furthermore, when the organic component in the glass paste contains a component that can be thermally polymerized, the volume change due to shrinkage caused by polymerization occurs makes removal of the paste from the mother mold even easier.

[0030] The following is another desirable manufacturing method for the plasma display in this invention: Glass paste mainly consisting of glass powder and an organic component is spread

on part or all of the surface of the a glass substrate at a uniform thickness. The mother mold is pressed onto the layer of glass paste to form the cell wall pattern. The pattern is sintered on the glass substrate at 400 to 600°C. The process steps occur in this order. In this manufacturing method, the ends of the grooves in the mother mold are tapered in the direction of depth.

[0031] This method forms a cell wall pattern by applying glass paste for cell walls on part or all of the surfaces of the glass substrate beforehand. The mother mold is pressed onto this layer of paste. The unnecessary paste is removed to form the cell wall pattern. The method of applying the glass paste uniformly on the glass substrate is not strictly limited. However, screen printing, die coating, or roll coating are good examples.

[0032] Figure 5 is a section of the mother mold which is suitable for the manufacturing methods above. The end 4 of the groove 3 in the mother mold is tapered. The mother mold can be made of polymer resin or metal as good examples. However, the first manufacturing method can use a silicon mold. In addition, the second manufacturing method can use a mother mold which has been polished or etched.

[0033] The glass paste used in this invention is made by mixing and kneading glass powder and organic components. Because plasma displays or plasma address liquid crystal displays are made using a glass substrates with low glass transition temperatures and softening temperatures, glass materials with 400 to 550 °C glass transition temperature and 450 to 580°C softening temperature should be used as cell wall materials. If the glass transition point is higher than 550°C and softening point is higher than 580°C, it is necessary to sinter at high temperature and the substrate may warp. On the other hand, materials with a glass transition point lower than 400°C and softening point lower than 450°C will not form a tight cell wall layer. This will cause delamination, broken wires, etc.

[0034] The coefficient of thermal expansion of high warping point glass used for the substrate is 80 to 90 x 10^{-7} / K. To prevent warping of the substrate and cracks in the panel seal, glass materials with a coefficient of thermal expansion ($\alpha_{50\ to\ 400}$) at 50 to 400°C of 50 to 90 x 10^{-7} / K, preferably 60 to 90 x 10^{-7} / K, should be used for both the cell walls and dielectric layer. By using glass materials which have the above features, it is possible to prevent delamination of the cell walls or broken wires.

[0035] The cell wall materials should have 3 to 60 wt. % silicon oxide in the glass. If it is less than 3 weight %, tightness, strength, and /or stability of the glass layer drops. The coefficient of thermal expansion will not be in the desired range, and mismatch with the glass substrate easily occurs. By making it less than 60 wt. %, the thermal softening point becomes low and etching the glass substrate becomes possible.

[0036] A specific example of the composition of suitable glass powder contains 30 to 90 wt. % metal oxide such as lead oxide, bismuth oxide, or zinc oxide. If it is less than 30 wt. %, controlling the softening point is difficult. On the other hand, if it exceeds 90 wt. %, stability of the glass becomes low, and the paste tends to have a short shelf life.

[0037] By using glass which includes 2 to 10 wt. % total of oxide of alkali metal such as sodium oxide, lithium oxide, or potassium oxide, etc., control of softening point and the coefficient of thermal expansion becomes easy. In the case when it is smaller than 2 %, control of softening point will be hard. On the other hand, if it is bigger than 10 %, luminosity drops due to evaporation of alkali metal oxide during the electric discharge. In addition, the amount of alkali

metal oxide should be less than 8 wt. % in order to improve stability of the paste also, preferably 6 wt. % or less.

[0038] Also, by using glass which contains both metal oxide such as lead oxide, bismuth oxide, zinc oxide such as the above and alkali metal oxide such as lithium oxide, sodium oxide, potassium oxide, controlling of softening point or linear thermal expansion coefficient becomes easy with a lower amount of alkali.

[0039] In addition, you can add aluminum oxide, barium oxide, calcium oxide, magnesium oxide, zinc oxide, and zirconium oxide to the glass powder. The diameter of the glass powder particles is selected considering the width or height of the cell walls to be manufactured. However, the 50 volume % particle diameter (average particle diameter D50) should be 1 to 6 μm, and the maximum particle diameter size should be 30 μm or less, and the relative surface area should be 1.5 to 4 m^2/g. Preferably, the 10 volume % particle diameter (D10) is 0.4 to 2 μm; 50 volume % particle diameter is 1.5 to 6 μm; 90 volume % particle diameter (D 90) is 4 to 15 μm; the maximum particle diameter size is 25 μm or less; and the relative surface area is 1.5 to 3.5 m^2/g. Also, if D 50 is 2 to 3.5 μm and the relative surface area is 1.5 to 3 m^2/g, it is even better.

[0040] At this point, D10, D50, and D90 are the particle diameters of 10 volume %, 50 volume %, and 90 volume % of the glass staring from the smallest particle diameter.

[0041] Although the particle diameter can be measured by any suitable method, laser diffraction-scattering methods are easy. For instance, the measurement conditions for a particle size distribution measurer HRA 9320-X100 manufactured by Micro Track is as follows:

[0042] Amount of sample: 1 g, dispersing condition: ultrasound dispersion for 1 to 1.5 minutes in purified water. If dispersion is difficult, it is done in a 0.2 % sodium hexamethalate solution.

[0043] The cell walls of this invention may contain 3 to 60 wt. % of filler with a softening point of 550 to 1200°C, preferably 650 to 800°C. By doing so, the shrinkage rate during sintering becomes small and pattern formation becomes easy, and the shape after sintering is improved.

[0044] The filler should be a high melting point glass powder which includes at least 15 wt. % of ceramics such as titania, alumina, barium titanate, zirconia, silicon oxide, or aluminum oxide. One example is the following glass powder composition.

[0045]

silicon oxide:	25 to 50 wt. %
boron oxide	5 to 20 wt. %
aluminum oxide	25 to 50 wt. %
barium oxide:	2 to 10 wt. %

The filler should have an average particle diameter of 1 to 6 μm. Its particle size distribution should be D10 (10 volume % particle diameter) is 0.4 to 2 μm; D50 (50 volume % particle diameter) is 1 to 3 μm; D90 (90 volume % particle diameter) is 3 to 8 μm; the maximum particle diameter is 10 μm or less for ease in forming the pattern. Even more preferably, D90 is 3 to 5 μm, and the maximum particle size is 5 μm or less. If D90 is 3 to 5 μm, it will be a fine powder which can reduce the sintering shrinkage rate. It also makes cell walls with low porosity. In addition, it is possible to make unevenness in the upper part of the cell walls ±2 μm or less. When powder with a big particle diameter is used for filler, not only does porosity go

up, but unevenness in the upper part of the cell walls becomes big. This causes extraneous electric discharge, which is not desired.

[0046] The organic component in the glass paste can be a cellulose compound represented by ethyl cellulose or an acryl polymer represented by polyisobutyl methacrylate. In addition, you can use polyvinyl alcohol, polyvinyl butyral, ester methacrylate polymer, ester acrylate polymer, ester acrylate – ester methacrylate co-polymer, α-methyl styrene polymer, butyl methacrylate resin, etc.

[0047] In addition, it is possible to use various kinds of additives if necessary. For example, if viscosity must be adjusted, an organic solvent can be added. Suitable organic solvents include methyl cellosolve, ethyl cellosolve, butyl cellosolve, methyl ethyl ketone, dioxane, acetone, cyclohexanone, cyclopentanone, isobutyl alcohol, isopropyl alcohol, tetrahydrofuran, dimethyl sulfoxide, γ-butylolactone, bromobenzene, chlorobenzene, dibromobenzene, dichlorobenzene, bromobenzoic acid, chlorobenzoic acid, terpineol, or a mixture of organic solvents which includes at least one these.

[0048] Glass paste is normally manufactured by the following method. Various components such as inorganic corpuscles, organic solvents, organic components, or additives that are added if required such as thickening agents, plasticizers, and precipitation preventing agents, etc are prepared in a predetermined ratio. They are mixed and dispersed uniformly using three rollers or a kneader.

The viscosity of the paste is adjusted freely depending on the amount of inorganic corpuscle or thickening agents. It is in the range of 2000 to 200,000 cps. For example, when application to the glass substrate is done by spin coating, 200 to 5000 cps is suitable. To improve shape retention after transferring the cell wall pattern to the glass substrate, 10,000 to 100,000 cps is desired.

[0049] Also, forming the dielectric layer on the glass substrate before formation of the cell walls is good for controlling delamination because it improves bonding with the cell walls.

[0050] The dielectric layer should be 5 to 20 μm, preferably 8 to 15 μm thick for uniformity. If the thickness exceeds 20 μm, it is difficult to remove after sintering, and cracks may occur. In addition, since the stress load on the substrate is high, the substrate may warp. Also, if the dielectric thickness is less than 5 μm, it is difficult to maintain uniformity.

[0051] When the dielectric layer is formed after the cell wall pattern is formed on the glass substrate, if it is formed by sintering the cell wall pattern and dielectric coating simultaneously, de-bindering of the dielectric coating and cell walls occur simultaneously. Therefore, shrinkage stress due to de-bindering of the cell walls is relieved. This can prevent delamination or broken wires compared to the case when sintering of the cell wall pattern and dielectric coating are done separately. When the cell walls and dielectric coating are sintered simultaneously, the number of process steps can be reduced also.

[0052] The dielectric layer in this invention should be made of glass with a main component with a coefficient of thermal expansion ($\alpha_{50 \text{ to } 400}$) at 50 to 400°C of 70 to 85 x 10^{-7} / K, preferably 72 x 80 x 10^{-7} / K. This is necessary for reducing sintering stress in the glass substrate. If the coefficient of thermal expansion exceeds 85 x 10^{-7} / K, the stress may cause the substrate to warp toward the dielectric layer. On the other hand, if the coefficient of thermal expansion is less than 70 x 10^{-7} / K, stress may cause the substrate to warp away from the

dielectric layer. Because of this, the substrate may crack if heating and cooling are repeated. In addition, there are times when the cell walls can not be attached to both the front and rear substrates because of warping.

[0053] When porosity is more than 10 %, in addition to a loss in adhesion, it will cause insufficient strength, and a loss in light-emitting characteristics such as luminosity due to absorption of moisture or gas leakage. Considering the desired functional life span of the panel and light-emitting features such as stable luminosity, 1 % or less is even better.

[0054] In each of the above manufacturing methods, the cell wall pattern formed on the glass substrate is sintered at 400 to 600°C to form the cell walls. Although the sintering atmosphere and temperature differ depending on the type of paste or substrate, sintering is done in air, nitrogen, hydrogen, etc. A batch type sintering oven or belt type continuous sintering oven can be used.

[0055] More specifically, sintering is done for 10 to 60 minutes at 400 to 600°C temperature while increasing the temperature at 200 to 400°C/hr. In addition, although the sintering temperature depends on the glass powder used, sintering should be done at an appropriate temperature where the pattern is not damaged and the shape of the glass powder does not remain.

[0056] If it is sintered at a temperature lower than the appropriate temperature, unevenness of the upper portion of the cell walls and porosity become big, or the lifespan of electric discharge becomes short, or it tends to cause mistaken electric discharge.

[0057] On the other hand, if it is lower than appropriate temperature, shape at formation of pattern is damaged. So, upper portion of parting walls become round, or the wall height will be extremely low, and the desired height cannot be attained.

[0058] Furthermore, an intermediate heating process at 50 to 300°C can be used between the main processes such as exposing, development, and sintering, in order to promote drying or pre-reactions.

[0059]

(examples of practice)

In the following, this invention is going to be explained more specifically using examples of practice. However, this invention is not limited to only these examples. Unless stated otherwise, all concentrations (%)in the examples of practice and examples of comparison are weight %.

[0060]

Glass powder (1):

composition:	Li_2O 7 %, SiO_2 22 %, B_2O_3 32 %
	BaO_4 5 %, Al_2O_3 22 %, ZnO 2 %
	MgO 6 %, CaO 4 %
Thermal property:	glass transition point 491°C, softening point 528°C
	The coefficient of thermal expansion 74 x 10^{-7}/K
Particle diameter:	D10 0.9 μm

D 50 2.6 μm
D 90 7.5 μm
maximum particle diameter: 22.0 μm
Relative surface area: 1.92 m^2/g
Refractive index: 1.59 (g line 436 nm)
Relative weight:2.54

Glass powder (2)
composition: Bi_2O_3 38%, SiO_2 7 %, B_2O_3 19 %
BaO 12 %, Al_2O_3 4 %, ZnO 20 %
Thermal property: glass transition point 475°C, softening point 515°C
The coefficient of thermal expansion ($\alpha_{50 \text{ to } 400}$)75 x 10^{-7}/K
Particle diameter: D 50 2.5 μm
D 90 3.9 μm
maximum particle diameter: 6.5 μm
Relative weight: 4.61
Polymer: ethyl cellulose
Solvent: terpineol
Plasticizer: dibutyl phthalate
Monomer: trimethylol propane triacrylate
Polymerization initiator: benzoyl oxide

Example of practice 1

First, a grinder was used to make a stripe shaped mold with 200 μm pitch, 30 μm width, and 200 μm height on an aluminum substrate. Next, silicon resin was used to fill the original mold, and a silicon mold 300 mm square with stripes with 200 μm pitch, 30 μm linear width, and 200 μm height was manufactured. This was used as the mother mold for the cell walls. Taper ends were formed on the original mold. The tapered part was 3 mm long at the ends of the silicon mother mold.

[0061] Next, 800 g of glass powder (1), 200 g of polymer, 50 g of plasticizer, and 250 g of solvent were mixed. They were mixed and dispersed using three rollers, and paste for cell walls with 9500 cps viscosity was manufactured.

[0062] Next, this paste for cell walls was used to fill the silicon mold using a doctor blade coater. After that, the mold was transferred to a 400 mm square glass substrate. The silicon mold was removed, and the cell wall pattern was formed.

[0063] Next, glass substrate with the cell wall pattern was sintered at 570°C for 15 minutes in air, and cell walls with 200 μm pitch, 30 μm width, and 200 μm height were formed.

[0064] The sectional shape of the end of the cell wall pattern was observed by scanning electron microscope (S-2400 manufactured by Hitachi).

[0065] As a result, X is 2.4 mm, Y is 120 μm, and X/Y = 20. This is in the range of this invention. In addition, there was no delamination or swelling at ends of cell walls.

[0066]

example of practice 2

First, stripe shaped grooves with 200 μm pitch, 30 μm width, and 200 μm height were etched on a 1 mm thick copper plate to form a mother mold. Etching was done so that the grooves that form the ends of the cell walls were a shallow tapered shape.

[0067] Next, 800 g of glass powder (2), 150 g of polymer, 50 g of plasticizer, 100 g of monomer, 10 g of polymerization initiator, and 250 g of solvent were mixed. They were mixed and dispersed using three rollers, and a paste for cell walls with 85 Pa·s viscosity was manufactured.

[0068] Next, this paste for cell walls was used to fill the mother mold using a doctor blade coater. After that, it was pressed on the 400 mm square glass substrate, and it was heated to 100°C for 30 minutes.

[0069] Next, the mother mold was removed, and a cell wall pattern was formed.

[0070] As a result of sintering as in example of practice 1, X is 2 mm, Y is 100 μm, X/Y = 20. This is in the range of this invention. In addition, there was no delamination or swelling at ends of cell walls, which was good.

Example of practice 3

[0071] First, 800 g of glass powder (2), 150 g of polymer, 50 g of plasticizer, 100 g of monomer, 10 g of polymerization initiator, and 250 g of solvent were mixed. They were mixed and dispersed using three rollers, and a paste for cell walls with 8500 cps viscosity was manufactured.

[0072] Next, this paste for cell walls was applied on glass substrate using a doctor blade so the paste would be 200 μm thickness.

[0073] Next, a mother mold with a 10 degree taper at the end of the stripe shaped grooves was etched on a 1 mm thich copper plate. The grooves had with 200 μm pitch, 30 μm width, and 200 μm height. This mother mold was pressed onto paste which had been applied on the glass substrate. While under pressure, it was heated to 80°C. After that, the mother mold was removed, and a cell wall pattern was formed.

[0074] As a result of sintering as in example of practice 1, X is 2 mm, Y is 100 μm, X/Y = 20. This is in the range of this invention. In addition, there was no delamination or swelling at ends of cell walls, which was good.

[0075]
Example of comparison 1

Except that the ends of the silicon mold used in example of practice 1 were changed to a right angle shape, cell walls was formed the same as example of practice 1.

[0076] When the photo-sensitive paste for cell walls was applied by screen printing, the length of the tapered edges of the coating was changed to 35 μm. Except for this change, it was the same as example of practice 1.

[0077] Since this paste would shrink to 63 % during sintering, if there is no delamination or swelling, the sintered shape would be X = 35 μm, Y = 100 μm, and H/Y = 0.35 after sintering. However, as a result of sintering under the same conditions as example of practice 1, 70 μm delamination was produced at the ends of the cell walls.

[0078]
Example of comparison 2

Except that the mother mold in example of practice 2 was changed to have right angled ends, cell walls were formed the same as example of practice 2.

[0079] Since this paste would shrink to 63 % during sintering, if there is no delamination or swelling, the sintered shape will be X = 35 μn, Y = 100 μm, and H/Y = 0.35 after sintering. However, as a result of sintering under the same conditions as example of practice 1, 90 μm delamination was produced at the ends of the cell walls.

[0080]
(Effects of this invention)

The plasma display in this invention has the following characteristics: This plasma display forms cell walls 2 using a mother mold and glass paste which mainly consists of glass powder and an organic component on a glass substrate 1. The ends of the cell walls are tapered. The height (X) of the cell walls and length (X) of the tapered part satisfy the following formula:

$1 \leq X / Y \leq 100$

Therefore, it has good bonding with the substrate and also has a good balance of stress during sintering shrinkage. Thus, it makes a high-precision plasma display which is free of delamination and swelling at the ends of the cell walls with less extraneous electrical discharge.

(Simple explanation of figures)

Figure 1: cross section of one example of the plasma display of this invention.

Figure 2: shows the height (Y) of the cell walls of this invention and length (X) of the tapered part of the cell walls.

Figure 3: side view of cell walls which shows delamination after sintering in a former plasma display.

Figure 4: side view of cell walls which shows swelling of the cell walls after sintering in a former plasma display.

Figure 5: section of a mother mold for cell walls used for manufacturing the plasma display in this invention.

(Explanation of symbols)
1, 1', 1": glass substrate
2, 2', 2": cell walls
3: grooves in the mother mold for cell walls
4: ends of the grooves in the mother mold for cell walls